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Patents Form 1/77

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Request for grant of a patent

(See the notes on the back of this form. You can also get an explanatory leaflet from the Patent Office to help you fill in this form)

1.	Your reference	P175-GB
2.	Patent application number *(The Patent Office will fill in this part)*	0324051.2
3.	Full name, address and postcode of the or of each applicant *(underline all surnames)*	1... Limited St John's Innovation Centre Cowley Road Cambridge CB4 0WS
	Patents ADP number *(if you know it)*	08113870001
	If the applicant is a corporate body, give the country/state of its incorporation	England
4.	Title of the invention	Loudspeaker
5.	Name of your agent *(if you have one)*	Ursula Lenel
	"Address for service" in the United Kingdom to which all correspondence should be sent *(including the postcode)*	1... Limited St John's Innovation Centre Cowley Road Cambridge CB4 0WS
	Patents ADP number *(if you know it)*	08113870001

		Country	Priority application number *(if you know it)*	Date of filing *(day / month / year)*
6.	If you are declaring priority from one or more earlier patent applications, give the country and the date of filing of the or of each of these earlier applications and *(if you know it)* the or each application number			

		Number of earlier application	Date of filing *(day / month / year)*
7.	If this application is divided or otherwise derived from an earlier UK application, give the number and the filing date of the earlier application		

8.	Is a statement of inventorship and of right to grant of a patent required in support of this request? *(Answer 'Yes' if:* *a) any applicant named in part 3 is not an inventor, or* *b) there is an inventor who is not named as an applicant, or* *c) any named applicant is a corporate body.* *See note (d))*	YES

Patents Form 1/77

9. Enter the number of sheets for any of the following items you are filing with this form. Do not count copies of the same document

Continuation sheets of this form	0
Description	7
Claim *(s)*	0
Abstract	0
Drawing *(s)*	0

10. If you are also filing any of the following, state how many against each item.

Priority documents

Translations of priority documents

Statement of inventorship and right to grant of a patent *(Patents Form 7/77)*

Request for preliminary examination and search *(Patents Form 9/77)*

Request for substantive examination *(Patents Form 10/77)*

Any other documents *(please specify)*

11. I/We request the grant of a patent on the basis of this application.

Signature Ursula Lenel Date 14-OCT-2003

12. Name and daytime telephone number of person to contact in the United Kingdom Ursula Lenel 01223-422290

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Notes

a) *If you need help to fill in this form or you have any questions, please contact the Patent Office on 08459 500505.*

b) *Write your answers in capital letters using black ink or you may type them.*

c) *If there is not enough space for all the relevant details on any part of this form, please continue on a separate sheet of paper and write "see continuation sheet" in the relevant part(s). Any continuation sheet should be attached to this form.*

d) *If you have answered 'Yes' Patents Form 7/77 will need to be filed.*

e) *Once you have filled in the form you must remember to sign and date it.*

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Loudspeaker

Author: R Topliss
Date: 10/10/03

Summary

This is a brief note explaining the function of the C Window loudspeaker, and 1 Ltd's concept for a manufacturing solution for the speaker.

The C Window is a speaker technology that allows a panel in the casework of various products, such as mobile phones and PDAs to be driven as a loudspeaker. It is described in the commonly owned international patent application number WO-03001841. There are several advantages to the technology:

- The speaker is very low profile, so does not take up much room inside the product.
- The C-morph piezoelectric actuator looks electrically like a capacitor, and consumes little power.
- For products that use a display, such as mobile phones, the speaker diaphragms may be the polycarbonate screens currently used to protect the LCD.
- Use of such speakers allows the product to be more effectively sealed against water and dust.
- The sound produced is diffuse, preventing hearing damage if used at loud volume close to the ear.
- The sound quality is superior to equivalent sized speakers.
- The parts and construction of the speaker are simple, potentially yielding cost advantages over traditional speakers.

Operation

Figure 1 shows the C-Morph actuator. The actuator is configured to operate like a bimorph. One free straight edge is rigidly connected to the edge of the diaphragm, and the other edge is connected to a solid base to provide the reaction force. When actuated, the C-Morph rotates the edge of the diaphragm as shown in figure 2.

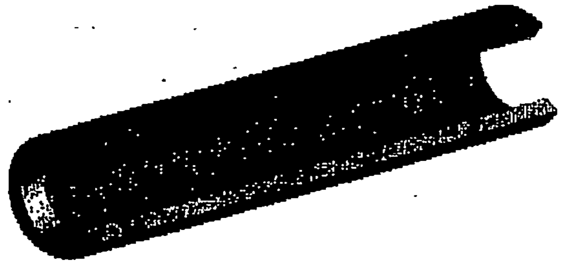

Figure 1: The C Morph actuator

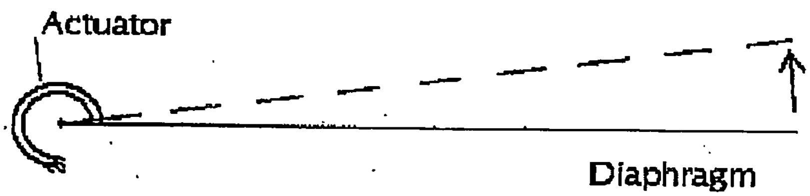

Figure 2: Operation of actuator

The diaphragm is typically supported in the product casework by a complaint surround. This may be a polyurethane foam, or a silicone sealant. This means that statically, the diaphragm is prevented from moving in the manner shown in figure 2. Figure 3 shows the results of an FEA analysis, where the actuator has deformed statically in response to an applied voltage. The displacement of the diaphragm has been amplified to make the effect more obvious.

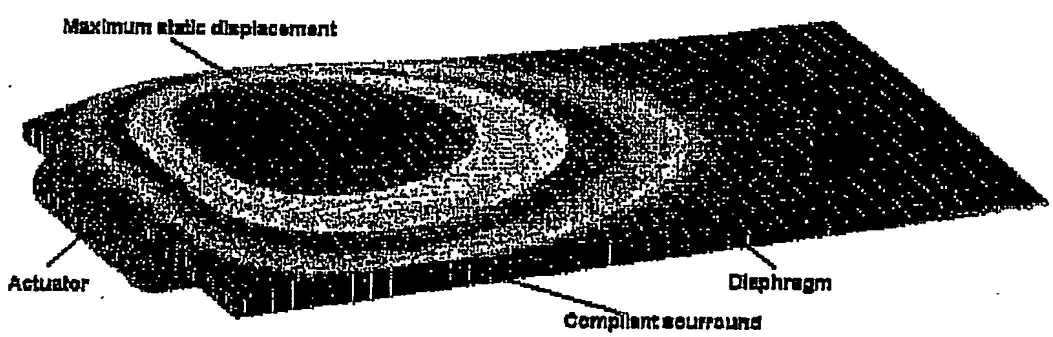

Figure 3: Static FEA analysis

In practice, the static displacement of the diaphragm bears little relation to the displacement of the diaphragm at the audible frequencies of interest.

The material used for the diaphragm, its stiffness and density determine the resonant frequencies of the diaphragm. For most applications, the material

properties of the diaphragm are such that it is operating above its first resonant frequency at the frequencies of interest. The resonant frequencies (and the fundamental frequency in particular) are also affected by the volume of air behind the diaphragm inside the product, since this adds stiffness to the system.

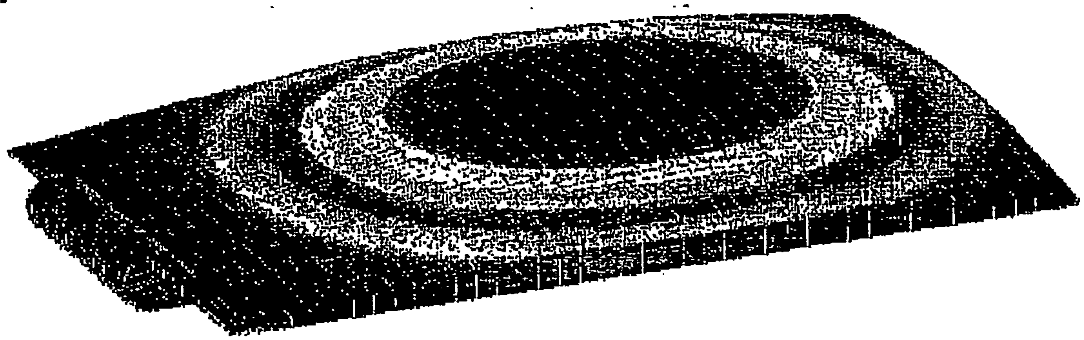

Figure 4: FEA analysis of fundamental resonance

Figure 4 shows how a typical diaphragm displaces at its fundamental resonant frequency. This particular analysis considers a diaphragm 44mm by 71mm made from 1mm thick polycarbonate, the same material currently used to protect LCD screens in mobile phones. Without any added air stiffness, this resonance occurs at approximately 380Hz.

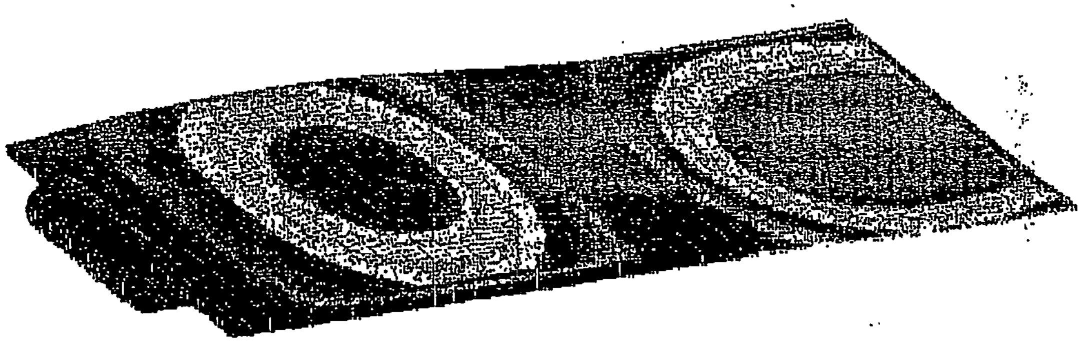

Figure 5: FEA analysis of first harmonic resonance

In contrast Figure 5 shows the results of the FEA analysis of the first harmonic of the diaphragm, for the same conditions as above. This occurs at approximately 650Hz. Therefore, in the audible region of interest, it is likely that the diaphragm will have 'broken up' and not move as a rigid body.

This has several implications:

- Above the first harmonic resonant frequency, the volume of air acting as a spring behind the diaphragm becomes far less important, because the diaphragm is not moving in phase. The air is not being asked to change volume, but merely shift from one place to another inside the product.
- At resonances, the amplitude of vibration of the diaphragm increases maximising the sound output.

- It does not matter that the actuator is only acting on one end of the diaphragm, since the energy travels across the diaphragm from the actuator.
- The frequency response is not a flat as a speaker operating as a piston. However, for its size, it operates at a lower frequency, and has a comparable flatness of frequency response to conventional voice coil speakers of similar size.

Design for Manufacture

The C Window speaker technology is a departure from conventional technologies, and has implications for the assembly processes for the product. 1 Ltd's aim is to minimise these changes to the assembly processes.

The final design of speaker is dependent on the application, however the example given is for a mobile phone application, where the diaphragm forms the protection for the LCD screen.

As explained above, the actuator acts to rotate the edge of the diaphragm. In order to do this, it needs to react against another part of the product. Due to the nature of PZT, it is also likely that the two ends of the actuator will need to be bonded to the diaphragm and the anchor point. In addition, the actuator must be protected from excessive stresses caused by external deflection of the diaphragm. If the actuator is rigidly mounted to the diaphragm and product casework, and yet the diaphragm is compliantly mounted to the casework, there is a danger of over stressing the actuator and breaking it. The nature of the tolerances of the compliant mounts for the diaphragm make designing suitable end-stops limiting the diaphragm movement difficult to implement in practice. Hence the basic design of C Window speaker must be modified to account for these issues.

In addition, most products are assembled by dropping functional sub-assemblies into the product casework. Integrating the speaker into the casework causes production problems because it potentially changes the responsibilities of different component manufacturers. All of these issues are addressed in 1 Ltd's concept design for manufacture.

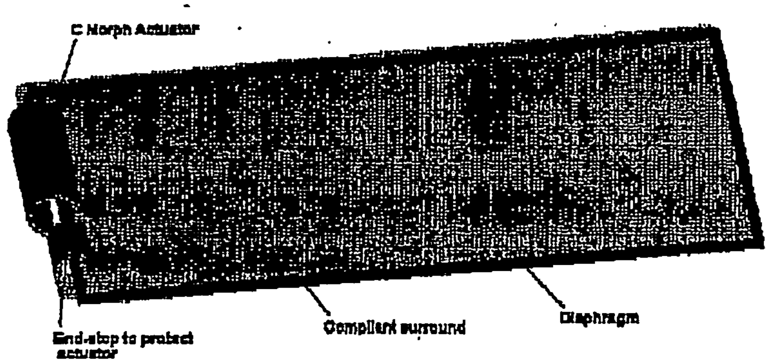

Figure 6: Concept design for manufacture

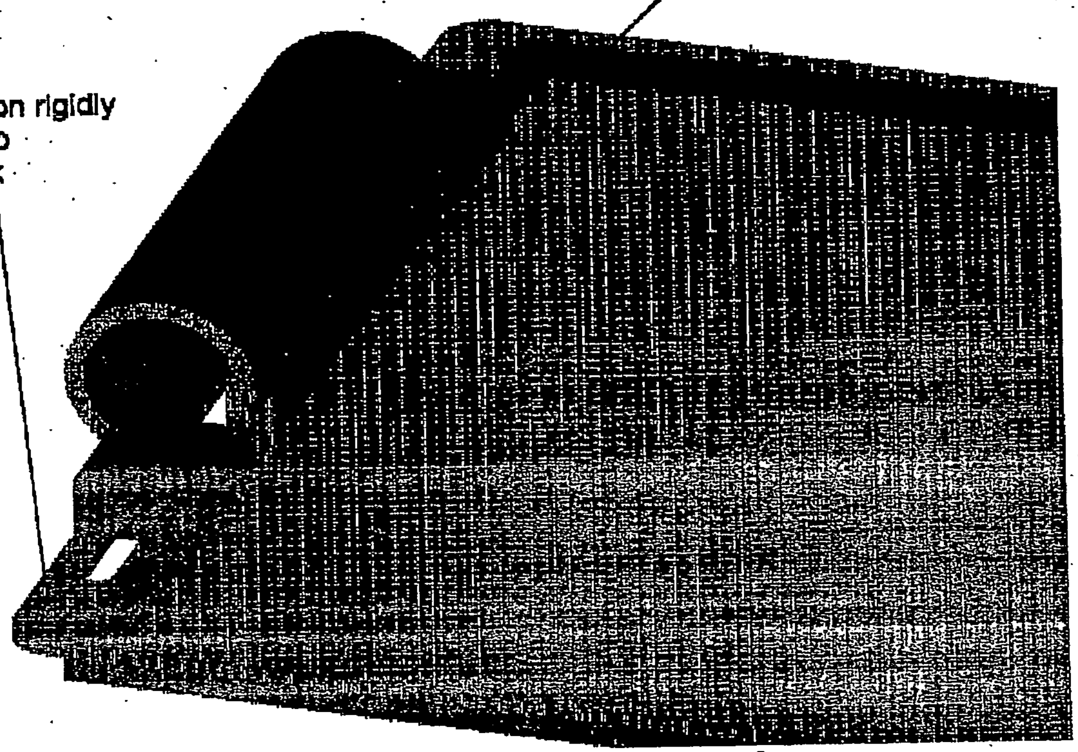

Figure 7: Close up of Actuator mounting

Figures 6 and 7 represent 1 Ltd's concept design that overcomes the problems highlighted above. Figure 6 shows that the C Window speaker can be manufactured as a single functional unit, that can undergo some form of performance testing before assembly into the product. The concept is designed such that it can undergo a single assembly operation into the product: There is no need to assemble the diaphragm, and then assemble the actuator to both the diaphragm and the casework.

Figure 7 shows more detail the basic features of the speaker needed to mount the actuator and provide for protection end-stops for the actuator. In essence, both ends of the actuator are bonded to the diaphragm, along with the end-stops. This minimises the complexity of assembling the actuator, and removes the tolerance issues in assembling the end-stops. In order to operate as described above, the left hand strip of the diaphragm in Figure 7 must be rigidly bonded to the product casework, whilst the region of the diaphragm visible from outside the product must be compliantly mounted. Figures 6 and 7 show dark strips of polyurethane foam providing this function, although alternative materials are possible.

By rigidly mounting the left hand strip to the product casework, this provides a good reaction against which the actuator can rotate and deform the diaphragm. Since the region bonded to the casework, and the moving diaphragm are joined at the diaphragm corners, this has the effect of stiffening the diaphragm and reducing its movement. However, this effect is quite small, and can be offset by a small increase in the size of the actuator. One practical

assembly method for the speaker, is to dispense a bead of compliant silicone around the seat for the diaphragm, and mounting area that needs to be rigidly constrained. By making the bond line much thinner in this area, this region will be much more stiffly bonded to the casework. Therefore the entire assembly process into the product casework may involve the dispensing of one material into the casework, and pressing the speaker module in place. This makes the assembly operation very similar to operations currently used in the assembly of such products.

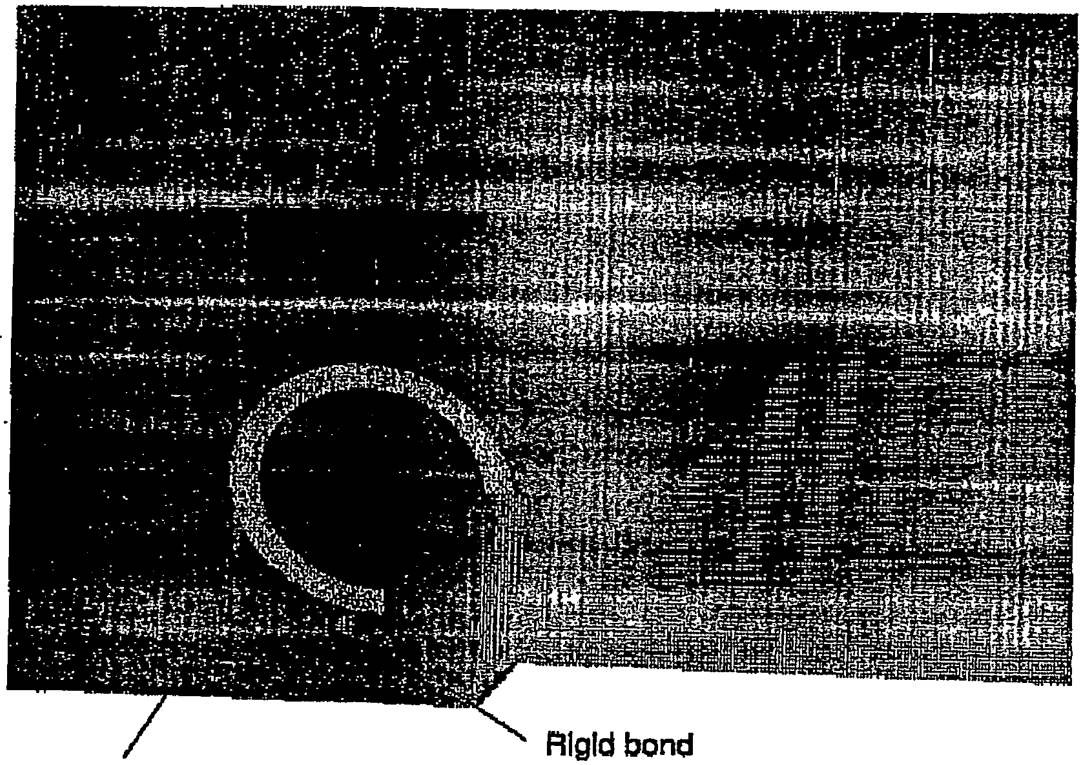

Figure 8: Cross-section view of speaker assembled in casework

Figure 8 shows how the speaker may be assembled into the product. In this case, the speaker is assembled from inside the product.

Figure 9 shows a speaker with an alternative form of actuator. In this case, the actuator is a piezoelectric bimorph connected at one end to the diaphragm and the other end to a stiff actuator mount. This mount forms a bridge section and is itself attached to the diaphragm. In the area where the mount is attached to the diaphragm, the diaphragm is rigidly mounted to the casework; at its other edges, the diaphragm is mounted on the casework through a compliant surround.

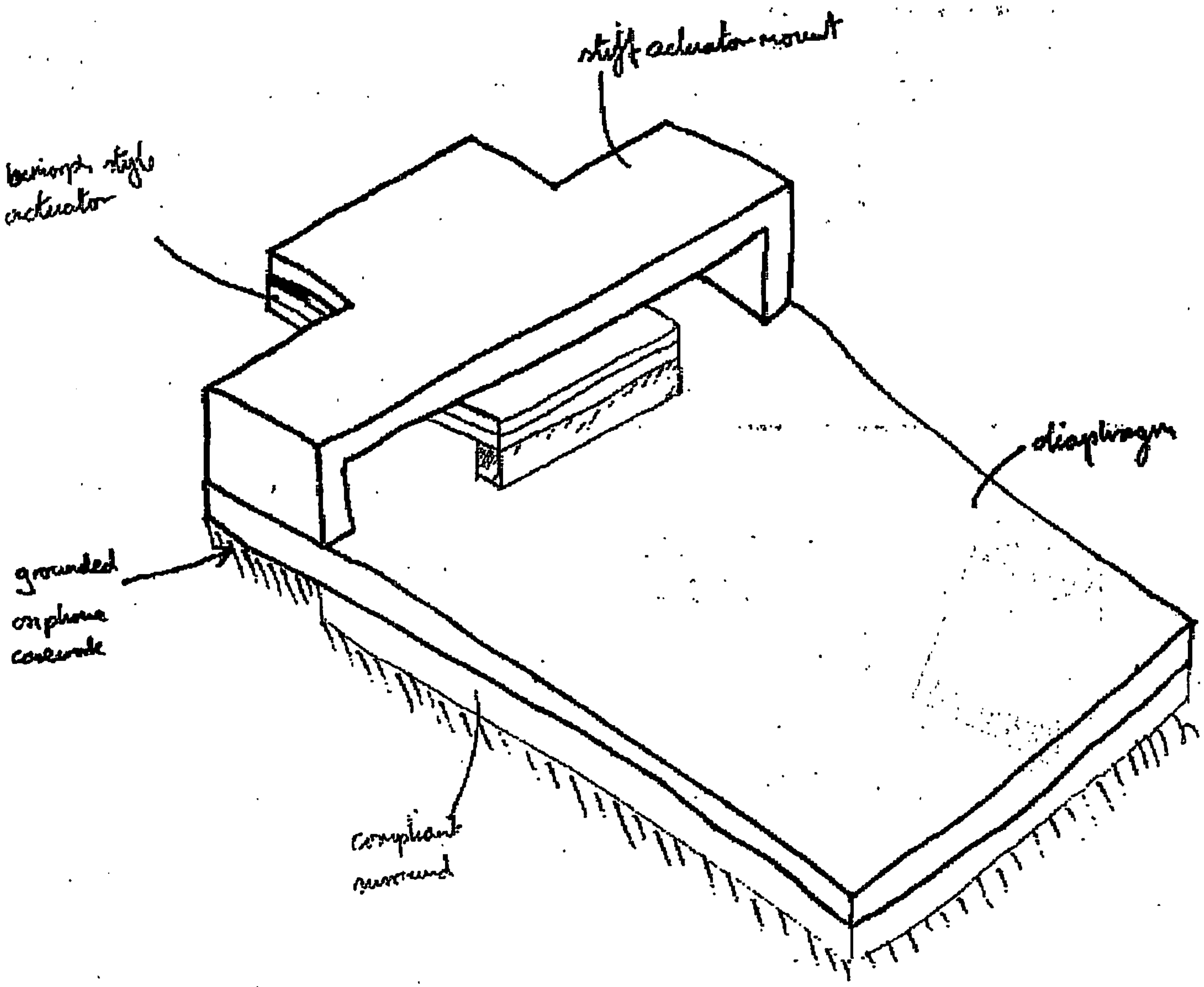
bimorph style actuator
stiff actuator mount
diaphragm
grounded earphone casework
compliant surround

FIGURE 9